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U. S. NAVAL AIR TEST FACILITY (SI)

LAKEHURST, NEW JERSEY

Report No. NATF(SI)-EI-114

3 May 1965

EVALUATION OF ALL AMERICAN ENGINEERING COMPANY'S
MODEL 44B-2 ARRESTING GEAR WITH
DEADLOADS AND AIRCRAFT

BUREAU OF NAVAL WEAPONS
PROBLEM ASSIGNMENT NUMBER RSSH-03-170/204/1



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Prepared by:

N. Cocco

N. Cocco

Recovery Division

Reviewed by:

C. T. Abrahamsen

C. T. Abrahamsen
Recovery Division

Approved by:

B. F. Kolacz

B. F. Kolacz

Superintendent of Engineering

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1. Introduction: An evaluation program of the All American Engineering (AAE) Company's Model 44B-2 arresting gear was conducted with deadloads at the Recovery Systems Track Site (RSTS) No. 5 of the U. S. Naval Air Test Facility (Ship Installations) (NATF(SI)), U. S. Naval Air Station, Lakehurst, New Jersey, as authorized by reference (a). The purpose of the deadload test program, financed by AAE (reference (b)), was to determine the basic performance characteristics of the arresting gear. Following these tests, further evaluation tests were conducted with the A-4B and F-104G aircraft, at the runway site of NATF(SI) as authorized by reference (c).

2. Description and Configuration

a. The Model 44B-2 arresting gear has a designed energy-absorption capacity of 68 million foot-pounds and a maximum runout of 1,000 feet. In its present configuration, as described below, the arresting gear is capable of absorbing the energy of five consecutive maximum-energy arrestments or ten maximum-energy arrestments in one hour.

b. The port and starboard arresting-gear units (see Figure 1) each consist of two basic components: the energy absorber and the retraction system.

(1) Energy Absorber: The energy absorber is composed of a 44-inch-diameter cylindrical drum that contains a nine-vaned rotor (33 inches in diameter) keyed to a vertical shaft and immersed in a solution of 60% ethylene glycol and 40% water. Eight stator blades are welded to the bottom of the drum and eight to the removable cover plate. The vertical rotor shaft extends through the cover plate and is keyed to a tape reel.

(2) Tape and Tape Reel: The tape reel has an outer diameter of six feet and an inner diameter of 18 inches, which consists of a 12-inch hub and a 3-inch collar. An 8-inch-wide x 0.356-inch-thick x 920-foot-long uncoated nylon purchase tape is reeved on the tape reel and threaded through a deck-edge sheave located 17 feet from the tape reel.

(3) Retraction System

(a) Electrical: A follower attached to the upper tape-reel flange bears up against a spring-loaded cam, mating the retraction system to the arresting system, and is used for retracting and pre-tensioning the system. System pre-tensions range from 1,500 to 2,000 pounds. During an arrestment, a tape tension of 5,000 pounds is needed to trip the cam and uncouple the retraction system from the arresting system. The spring-loaded cam (see Figure 2) is mounted to a sprocket and connected, through a drive chain, to a gear-reduction box which is

driven by a 20-horsepower electric motor. The retraction and pre-tensioning is accomplished by operating an ON-OFF electrical switch on the shell covering the retraction system. To retract a 1,000-foot purchase tape and to pre-tension the system takes approximately three minutes.

(b) Mechanical: A capstan is connected to the upper flange of the tape reel in order that mechanical retraction of the system may be accomplished in the event of failure of the electric retraction system. The arresting gear can then be retracted by wrapping rope around the capstan and pulling with a vehicle. Retracting both units through the use of a capstan can be accomplished within approximately ten minutes.

(4) Tight Tape Wrap: A roller, shown in Figure 3, is utilized to obtain a tight tape wrap. By means of a winch, a 600- to 1,200-pound load is applied to the roller, which forces the roller against the tape, pressing the tape to the stack.

c. The arresting-gear was configured to a deck-sheave span of 225 feet, with a 17-foot split from the sheave to the tape reel (both port and starboard). The following deck pendants were used:

(1) Deadload tests - 115- and 150-foot-long x 1-inch-diameter, nonrotating, hemp-core deck pendants, and

(2) Aircraft tests - 135-foot-long x 1-inch-diameter, non-rotating, hemp-core deck pendants.

d. The energy absorber and retraction system are mounted on a steel plate that is anchored to the deck by three deadmen and ground stakes. The deck-edge sheaves are anchored to the deck by three deadmen. The above-ground height of the energy absorber and the retraction motor is 22 and 32 inches respectively.

3. Test Results and Analysis

a. Deadload Tests: Fifteen arrestments of various-weight deadloads were conducted at RSTS No. 5 and are summarized below:

Deadload Weight (Lb)	No. of Events	Range		Purchase- Tape Tension* (1,000 Lb)	Deck- Pendant Length (Ft)
		Engaging Speed (Kn)	Arresting- Hook Axial Load (1,000 Lb)		
20,000	7	116 - 185	29.5 - 66.8	14.6 - 35.5	115/150
24,000	1	172	60.8	34.2	150

* Measured by three-sheave tensiometers.

Deadload Weight (Lb)	No. of Events	Engaging Speed (Kn)	Range		Deck- Pendant Length (Ft)
			Arresting- Hook Axial Load (1,000 Lb)	Purchase- Tape Tension* (1,000 Lb)	
30,000	3	141 - 169	42.0 - 63.8	21.0 - 31.3	150
40,000	4	123 - 169	34.0 - 75.0	16.8 - 33.0	150

* Measured by three-sheave tensiometers.

(1) The use of different-length pendants during arrestments of the 20,000-pound deadload did not result in any significant difference in arresting-gear performance.

(2) Both arresting-gear units two-blocked during all events with the 40,000-pound deadload; the arresting-hook loads at time of two-blocking were negligible, and caused deadload walkbacks of less than 100 feet. Wet purchase tapes were used during two events with this deadload (158- and 169-knot engaging speeds), and resulted in no significant variations in arresting-hook loads and purchase-tape tensions.

(3) For the 15 deadload events, the working limit of the purchase tapes was set at 55,000 pounds and the working strength of the pendant was set at 46,000 pounds.

(4) Appendix A is a tabulation of all pertinent data. Plots of maximum arresting-hook axial load and purchase-tape tension versus engaging speed are presented in Figures 4 and 5 respectively.

b. Aircraft Tests: Eleven arrestments of the A-4B and F-104G aircraft were conducted at the runway site and are summarized below:

Aircraft		No. of Events	Engaging Speed (Kn)	Range		Deck- Pendant Length (Ft)
Type	Weight (Lb)			Arresting- Hook Axial Load (1,000 Lb)	Purchase- Tape Tension (1,000 Lb)	
A-4B	15,000	4	113 - 138	16.9 - 33.8	12.2 - 21.0	135
F-104G	17,000	7	114 - 173	20.9 - 58.0	14.0 - 30.4	135

(1) Results

(a) Inspection of the A-4B aircraft after each arrestment indicated that the arresting hook was impacting the aircraft fuselage; however, the impacts were mild and no aircraft damage was observed.

(b) The F-104G aircraft fuselage was damaged during these tests. Although the hook-impact area on the aircraft occurs at the center of the parachute door, the damage inflicted was observed fore and aft of this point. This damage consisted of buckling of the parachute door outer surface and internal damage on the door frame and pulley assembly (see Figure 6). The aircraft parachute door used during these tests had been reinforced. (Note: Based on later tests with the M-21G arresting gear, there is a strong indication that the arresting-hook snubber assembly of this aircraft was not functioning properly during the above tests.)

(c) Appendix B is a tabulation of all pertinent data. Plots of maximum arresting-hook axial load and purchase-tape tension versus engaging speed are presented in Figures 7 and 8 respectively.

(2) Aircraft Performance

(a) The following pilot technique was used during all aircraft arrestments:

1. Maintain throttle setting needed to obtain the required engaging speed until wire pick-up.
2. Reduce throttle setting to idle after wire pick-up is assured and maintain at this position for the remainder of the arrestment.
3. When the aircraft speed is reduced to a speed comparable to a taxi speed, apply brakes until aircraft is completely stopped.

(b) The energy-absorption characteristics of the arresting gear, that is, the retarding torque, is proportional to the arrested vehicle's speed; therefore, the technique described above was used to prevent two-blocking of the arresting gear. This method proved to be satisfactory.

(c) At the conclusion of each aircraft arrestment, assistance was needed to disengage the pendant from the aircraft hook. This was accomplished with the A-4B aircraft by cautiously retracting the arresting gear, thereby moving the aircraft backward; and then, by stopping the retraction, the aircraft would roll away from the pendant. The shape of the F-104G aircraft made this method impractical because of possible aircraft damage; therefore, the pendant was removed by connecting a vehicle to the tape connector by means of a rope and pulling on the tape until the tape became slack. When the tape was slack, the pendant was manually removed from the hook.

(d) Pilot comments for all arrestments of both aircraft were favorable. No yaw was noticed at any time, and the maximum final OFF-CENTER distance of the aircraft varied by less than 10 feet from the wire pick-up position. The deadload tests at RSTS No. 5 verified this negligible OFF-CENTER tracking characteristic.

c. Deck-Pendant Service Life: Nine 1-inch-diameter deck pendants were used during the 26 arrestments conducted for this program. The following table gives pertinent pendant information and the reason replacement was required:

<u>No. of Engagements on Deck Pendant</u>	<u>Highest Engaging Speed (Kn)</u>	<u>Reason for Replacement</u>
5	185	5 broken wires
1	145	Deadload guides cut through pendant
3	171	Internal damage of pendant indicated
5	169	2 broken wires and excessive number of flat spots
2	172	Completion of deadload tests
2	125	Bolter - A-4B aircraft arresting hook speared pendant
0	-	Bolter - A-4B aircraft arresting hook speared pendant
7	154	Considered unacceptable for further use
2	175	Completion of aircraft tests

d. Arresting-Gear Maintenance: The arresting gear required no major maintenance during this program.

(1) The following minor maintenance was required prior to aircraft tests:

(a) Three gallons of arresting-gear fluid was added to each unit.

(b) Approximately one quart of fluid was added to the fluid couplings located between the electric retraction motor and the gear-reduction box.

(c) The nylon purchase tapes were reversed; that is, the loops that were connected to the pendant were reversed and connected to the tape-reel hubs. This was performed because of the excessive amount of purchase-tape wear experienced during the deadload tests at RSTS No. 5, which was caused by the terrain over which the purchase tapes traveled during an arrestment.

(2) When required during the test program, a coating of GACO was painted on those areas of the purchase tapes where excessive wear was occurring.

4. Comparison of Various Emergency Arresting Gears: The performance of the Model 44B-2 arresting gear indicates that it may be a highly-desirable replacement for emergency arresting-gear systems now in use. In support of this statement, the comparisons contained on the following pages are presented for the Model 44B-2, E-5-1, E-14-1, and E-27 arresting-gear systems. The comparison information was extracted from the following sources:

a. E-27 - NATF(SI) report number NATF(SI)-EI-110 of 20 Nov 1964, subject: Aircraft Compatibility with Single E-27 (BAK-9 Pit Installation) Emergency Arresting Gear.

b. E-14-1 - NATC report number 1 of 20 Dec 1960, subject: Evaluation of the E-14-1 "Water Squeezer" Runway Emergency Arresting Gear with Airplanes, Report No. 1, Final Report; and NATF(SI) ltr 4210/ANB:jas of 5 Feb 1965, subject: Service-life evaluation of swivels for the E-14-1 emergency arresting gear.

c. E-5-1 - NATF(SI) report number NATF-E-1049, SUPPL A, of 12 Apr 1962, subject: Evaluation of the E-5-1 Emergency Chain Arresting Gear Performance with Piloted Aircraft.

d. 44B-2 - This report; extrapolated from tabulated test data, in Appendixes A and B. F-8 and A-3 aircraft test data, extrapolated from deadload test data, in Appendix A.

Performance

Type Aircraft	Engaging-Speed Limit (Knots)		
	<u>E-27</u>	<u>E-14-1</u>	<u>E-5-1</u> <u>44B-2</u>
A-3	130	160	152 177
A-4	160	168	162 180
F-8	160	154	162 180

NOTE: Figure 9 of this report presents these engaging-speed limits in bar-graph form.

Purchase-Tape Service Life

<u>E-27</u>	<u>E-14-1</u>	<u>E-5-1</u>	<u>44B-2</u>
Maximum of 20 arrestments. Cable and swivel inspected after 10 arrestments, provides tape replacement and replaced after 20 arrestments for this gear.	Cable and swivel inspected after 10 arrestments, and replaced after 20 arrestments.	Report NATF-E-1049 Supplement A states a maximum of 28 arrestments before replacement.	Because of past performance of similar tapes used on TM-24 arresting gear, the anticipated service life is 50 arrestments.

Installation

Gear is installed in deep pit on side of runway with fairlead tubes under runway. Deck sheaves are mounted on each side of runway.	Two ditches are needed, one on each side of runway, 5-ft wide, approx 5-ft deep, and 920-ft long, which contain 920 feet of programmed tubes. Three concrete pits are incorporated around each tube assembly. Deck-edge sheaves are mounted on each side of runway.	A concrete pad is needed on each side of runway to anchor the pre-tension system. Retention "hooks" are bolted into the runway.	Arresting gear and deck-edge sheaves are secured to ground by deadmen and ground stakes. If pits are needed, the size of the gear allows for small pits.
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<u>Retraction Time</u>			
<u>E-27</u>	<u>E-14-1</u>	<u>E-5-1</u>	<u>44B-2</u>
3 to 4 minutes.	6 minutes.	Approximately 20 minutes.	1 to 2 minutes.
<u>Maintenance</u>			
<p>A great deal of maintenance is required; this includes:</p> <p>a. Repair of hydraulic leaks.</p> <p>b. Frequent replacement of brake-selector valves, shuttle valves, and re-wind shear pins.</p> <p>c. Balancing of the hydraulic system so that the programmed hydraulic pressure is the same on both units.</p> <p>d. Frequent replacement of friction brakes, particularly after a series of high-energy engagements.</p>	<p>Little maintenance is required; this includes:</p> <p>a. Periodic disassembly and inspection of swivels.</p> <p>b. Filling each unit with additional arresting gear fluid every 2 or 3 arrestments.</p> <p>c. Replacement of shear pins in pre-tension system after each arrestment.</p>	<p>Little maintenance is required; this includes:</p> <p>a. Replacement of shear pins in pre-tension system after each arrestment.</p> <p>b. Tightening of anchoring system after approximately 50 arrestments.</p>	<p>Little maintenance is expected; this includes:</p> <p>a. Filling each unit with additional arresting gear fluid each day.</p>

5. Conclusions

a. In its present configuration, the AAE Model 44B-2 arresting gear can arrest the F-104G aircraft at engaging speeds up to 170 knots without exceeding either the aircraft's designed maximum deceleration or arresting-hook axial load limit.

b. The engaging-speed limit for the A-4 aircraft is extrapolated as being in excess of 170 knots.

c. No aircraft damage was incurred when testing with the A-4 aircraft. Because all A-4 testing was conducted below a speed of 140 knots, no definite conclusions can be made as to the extent of aircraft fuselage damage that can be expected during high-speed arrestments.

d. The deadload test results indicate that all Navy aircraft up to a gross weight of 40,000 pounds can be arrested at speeds in excess of 160 knots without exceeding design limitations if the landing techniques described in paragraph 3b(2)(a) are used.

6. Recommendations

a. Further deadload testing with the Model 44B-2 arresting gear should be conducted in order to obtain data for a complete evaluation of arresting-gear/deadload performance.

b. The Model 44B-2 arresting gear should be considered as a replacement for the emergency arresting-gear systems now being used at shorebased installations.

7. References

(a) BUWEPS msg 102054Z of Mar 1964

(b) AAE ltr CA-1065 of 10 Sep 1964

(c) BUWEPS ltr RSSH-30/3:KEG of 27 Jan 1965

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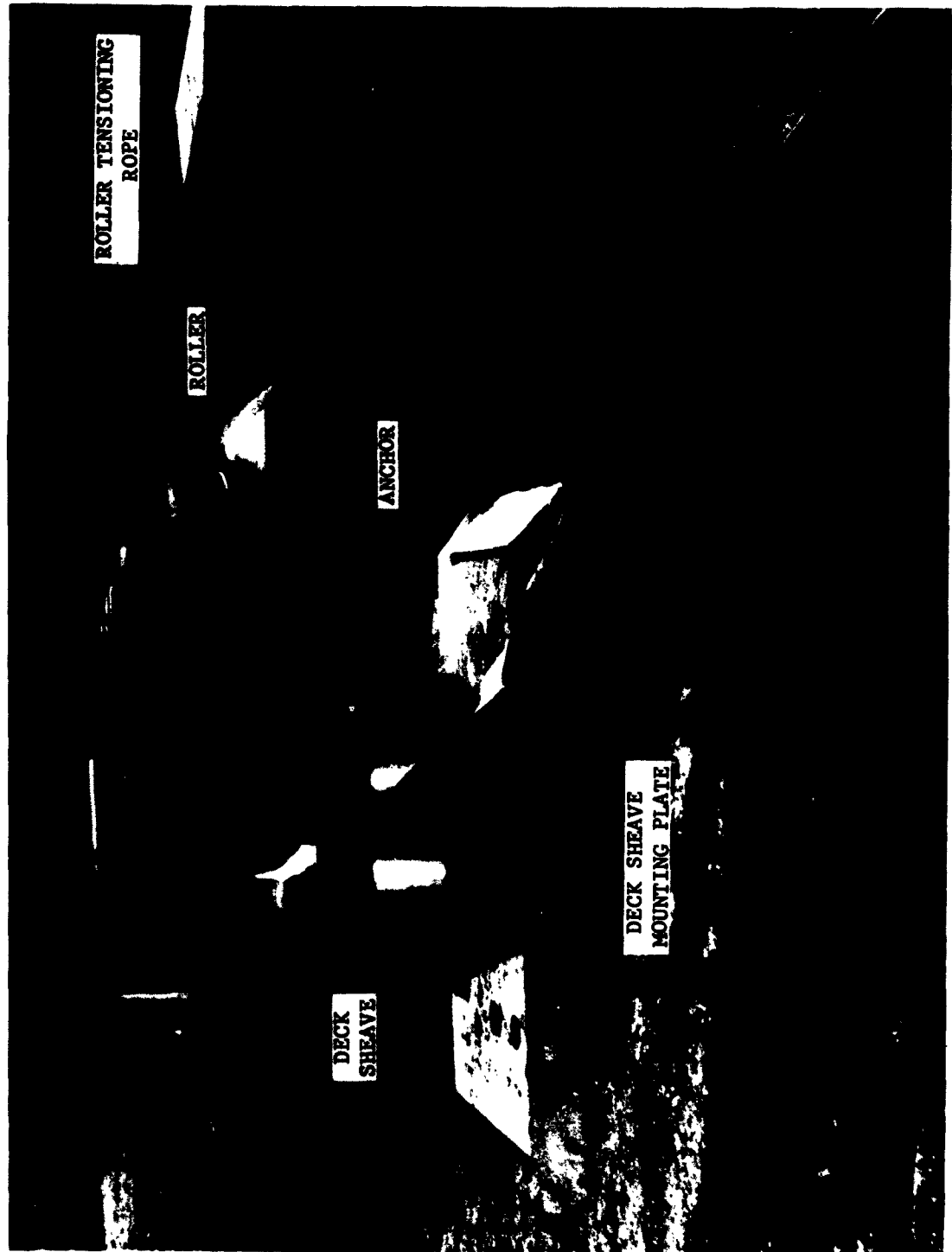


Figure 1 - View of AAE Model 44B-2 Arresting-Gear Unit - Port

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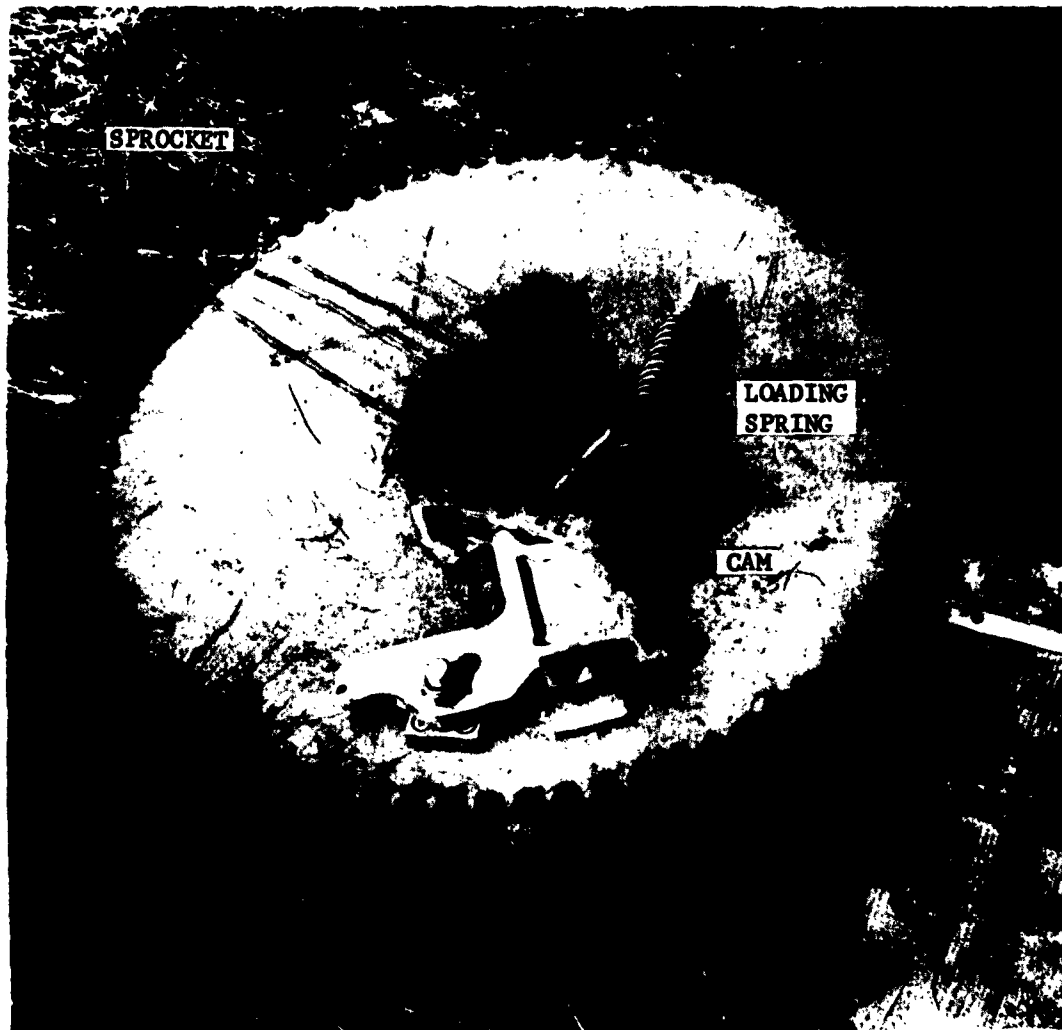


Figure 2 - Retract Cam in Unloaded Position (AAE Model 44B-2
Arresting Gear)

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Figure 3 - View of AAE Model 44B-2 Arresting-Gear Unit Showing Retract
Roller in Unloaded Position

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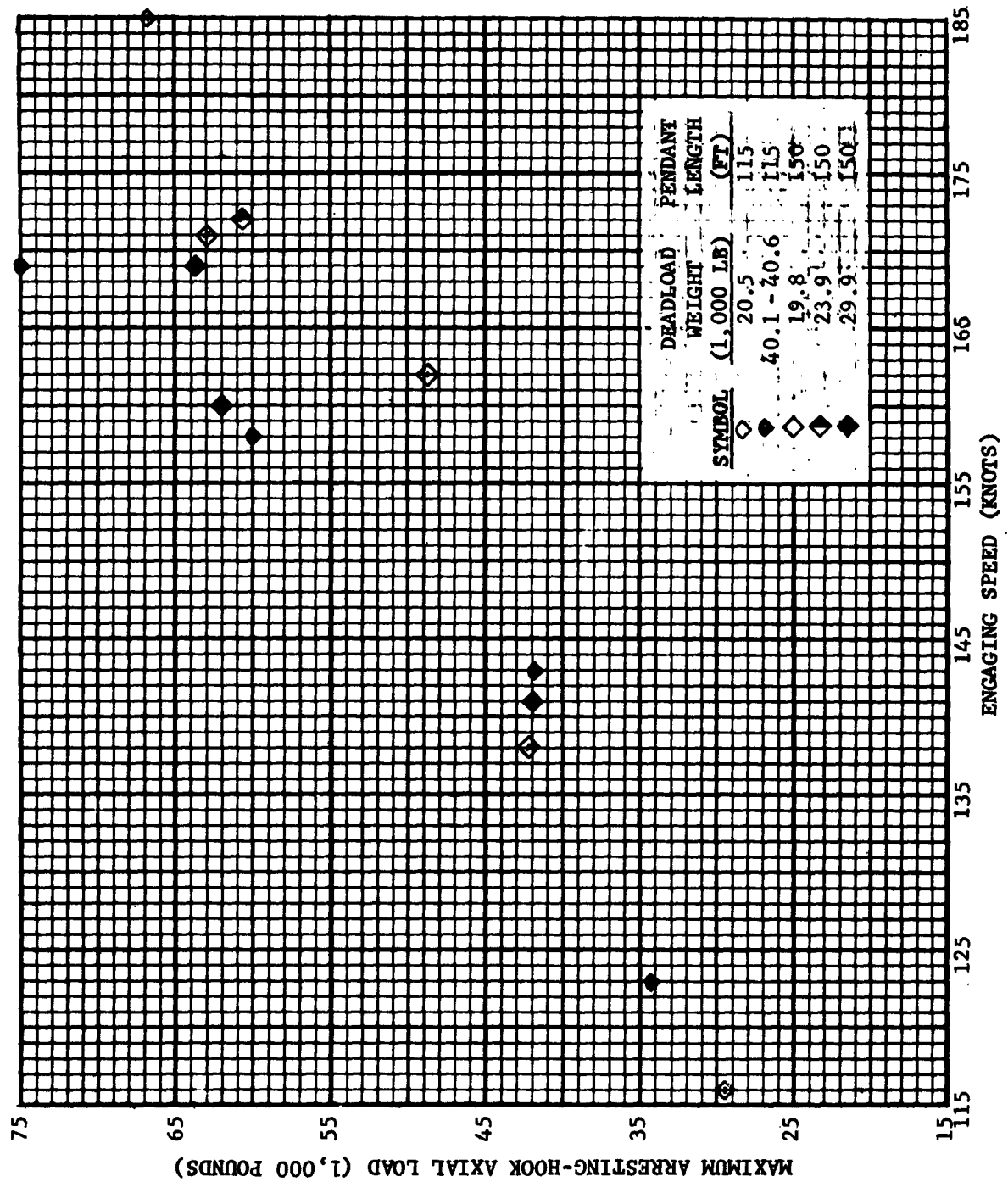


Figure 4 - Maximum Arresting-Hook Axial Load versus Engaging Speed - Deadload Arrestments (AAE Model 44B-2 Arresting Gear)

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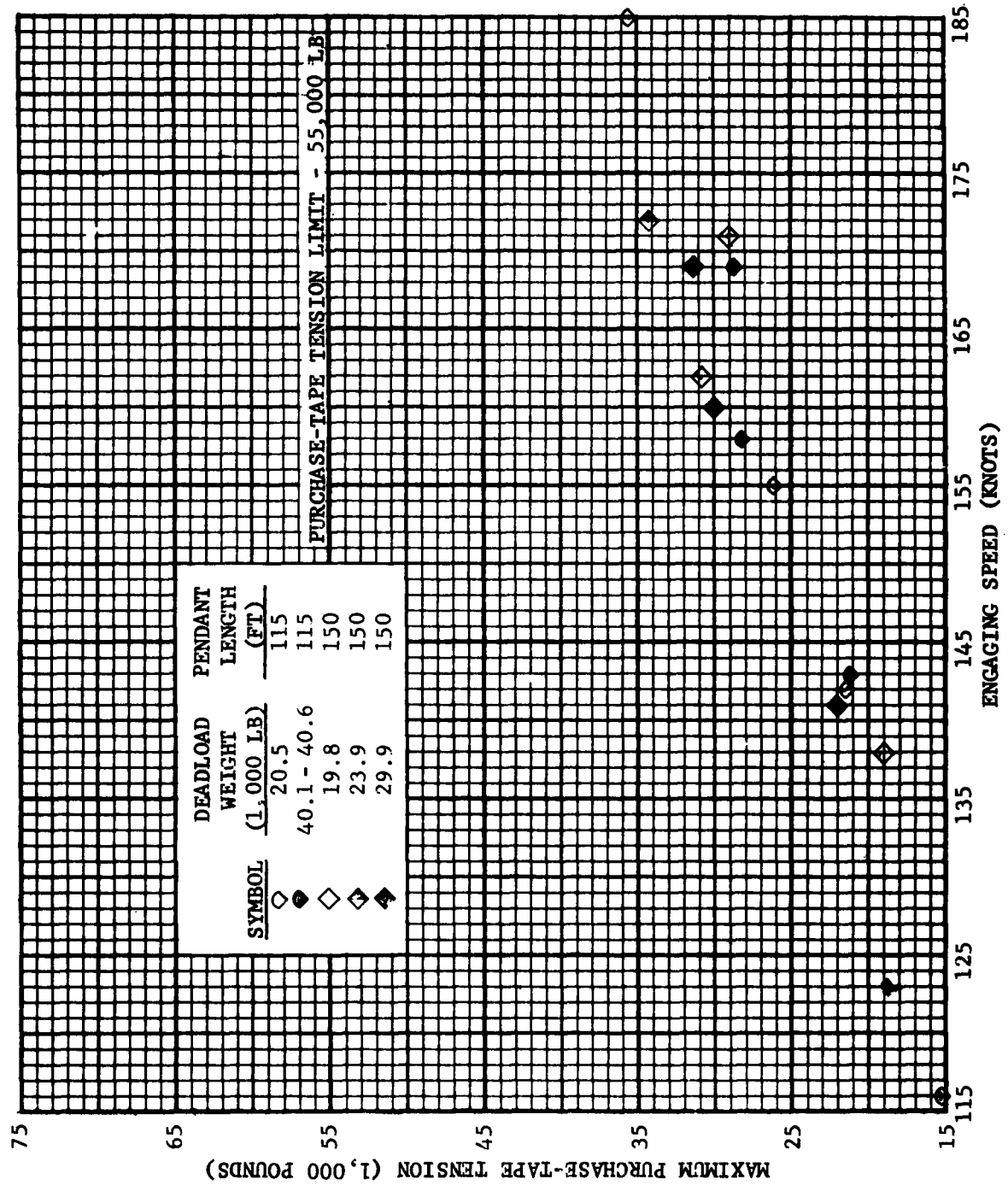


Figure 5 - Maximum Purchase-Tape Tension versus Engaging Speed - Deadload Arrestments (AAE Model 44B-2 Arresting Gear)

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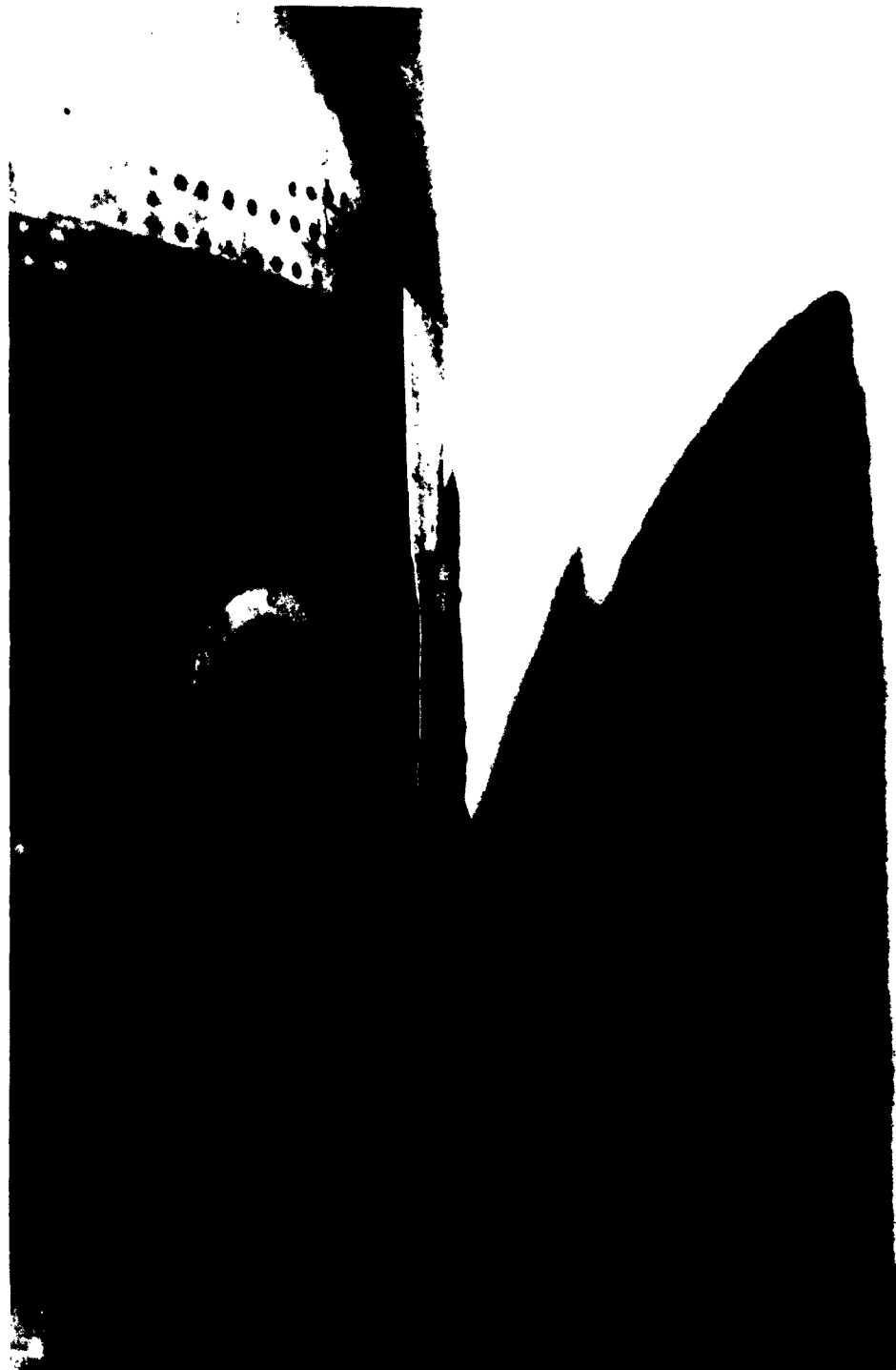


Figure 6 - View of Damage to the F-104G Aircraft Parachute Door Resulting from
Arresting-Hook Impact during AAE Model 44B-2 Arresting-Gear Tests

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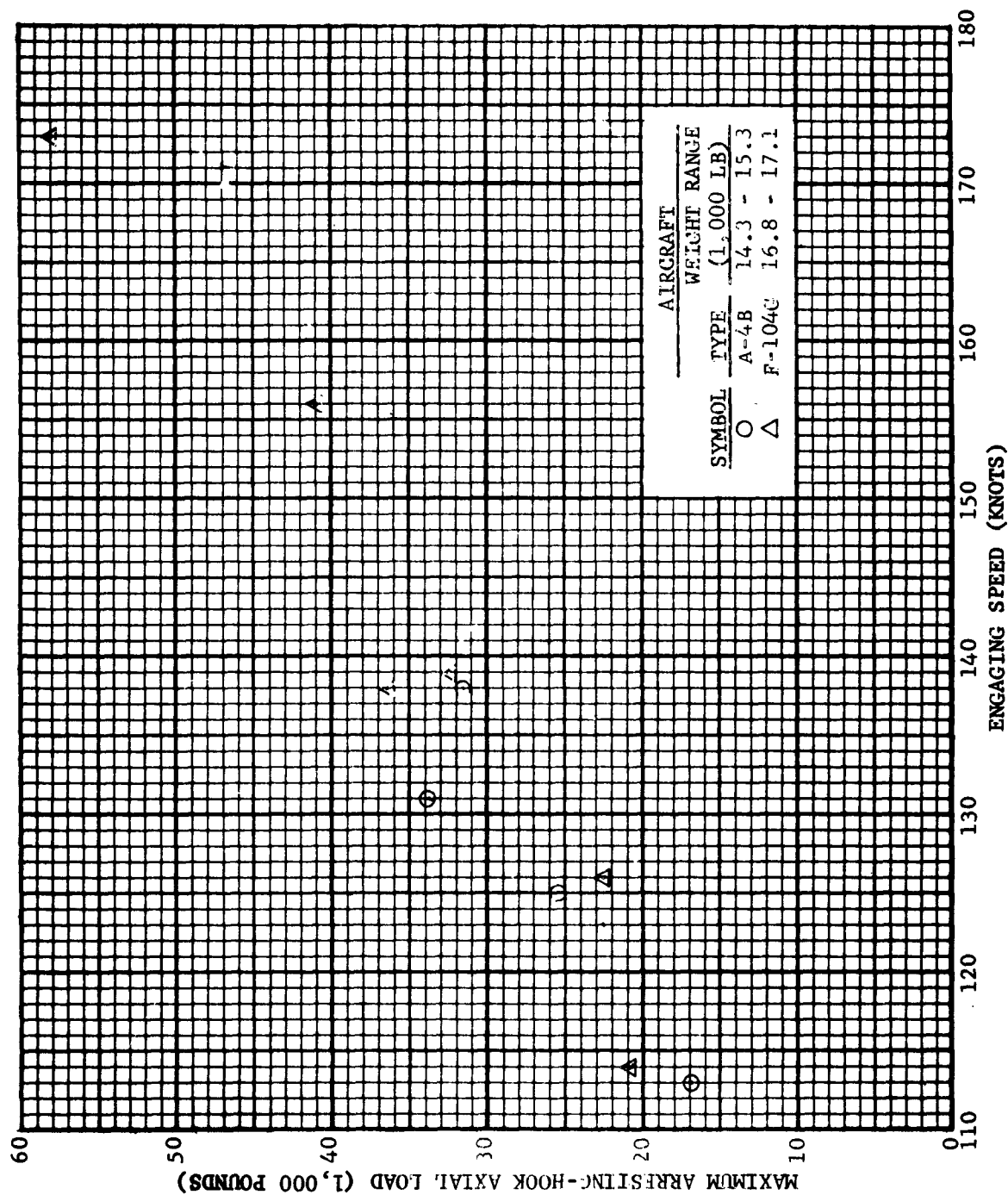


Figure 7 - Maximum Arresting-Hook Axial Load versus Engaging Speed - Aircraft Arrestments (AAE Model 44B-2 Arresting Gear)

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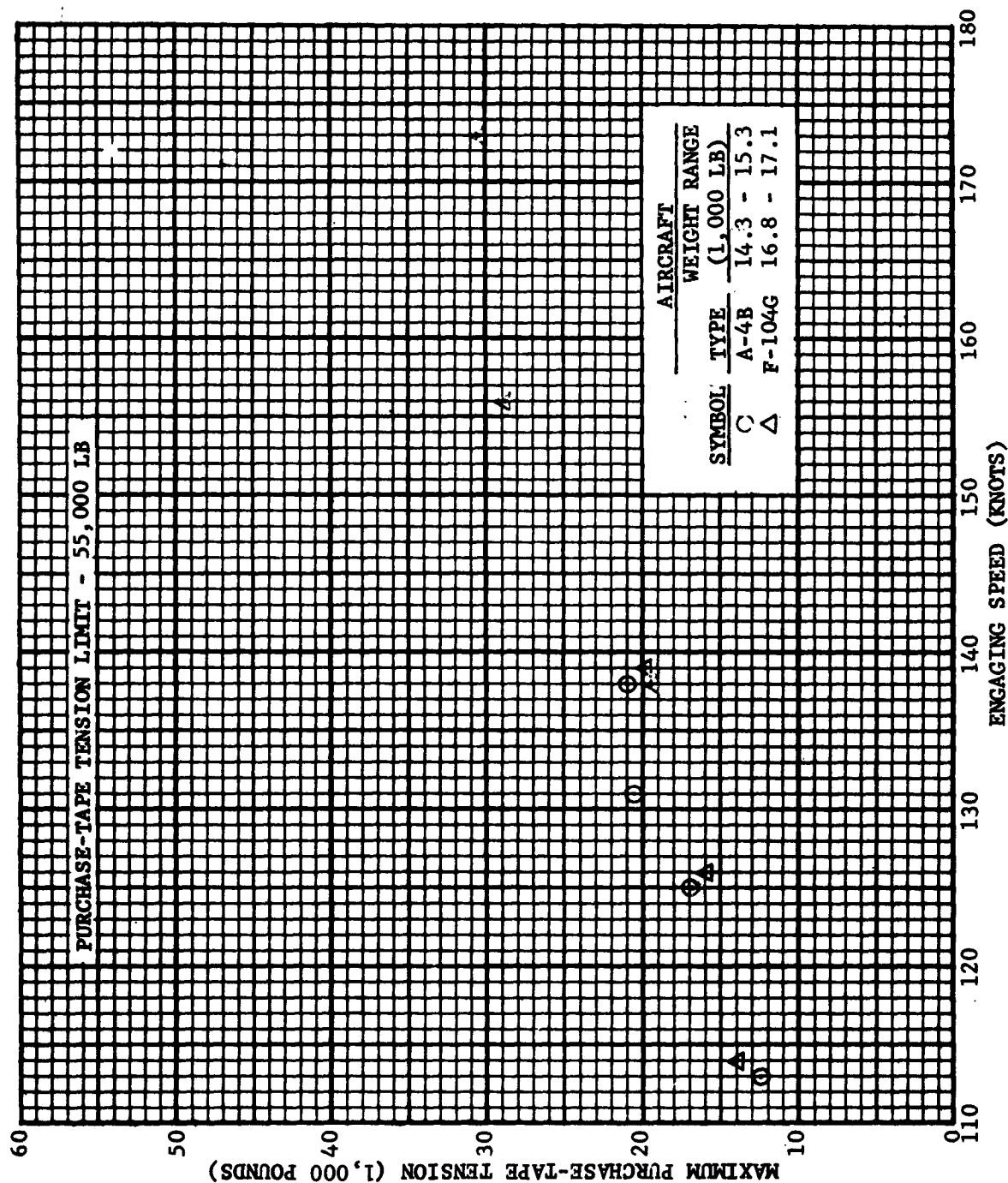


Figure 8 - Maximum Purchase-Tape Tension versus Engaging Speed - Aircraft Arrestments (AAE Model 44B-2 Arresting Gear)

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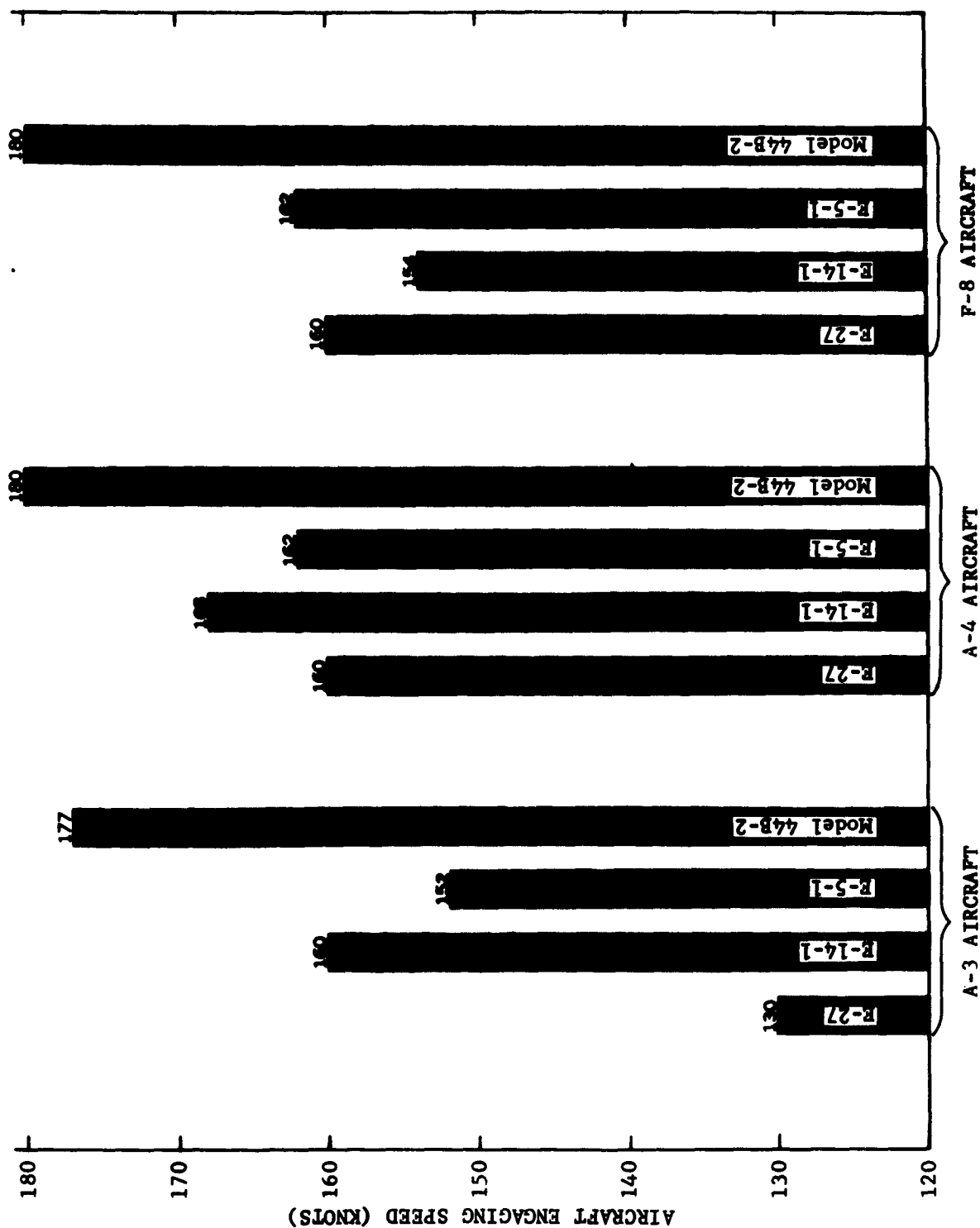


Figure 9 - Bar Graph of Aircraft Engaging-Speed Limits on Various Emergency Arresting Gears (AAE Model 44B-2 Arresting-Gear Evaluation)

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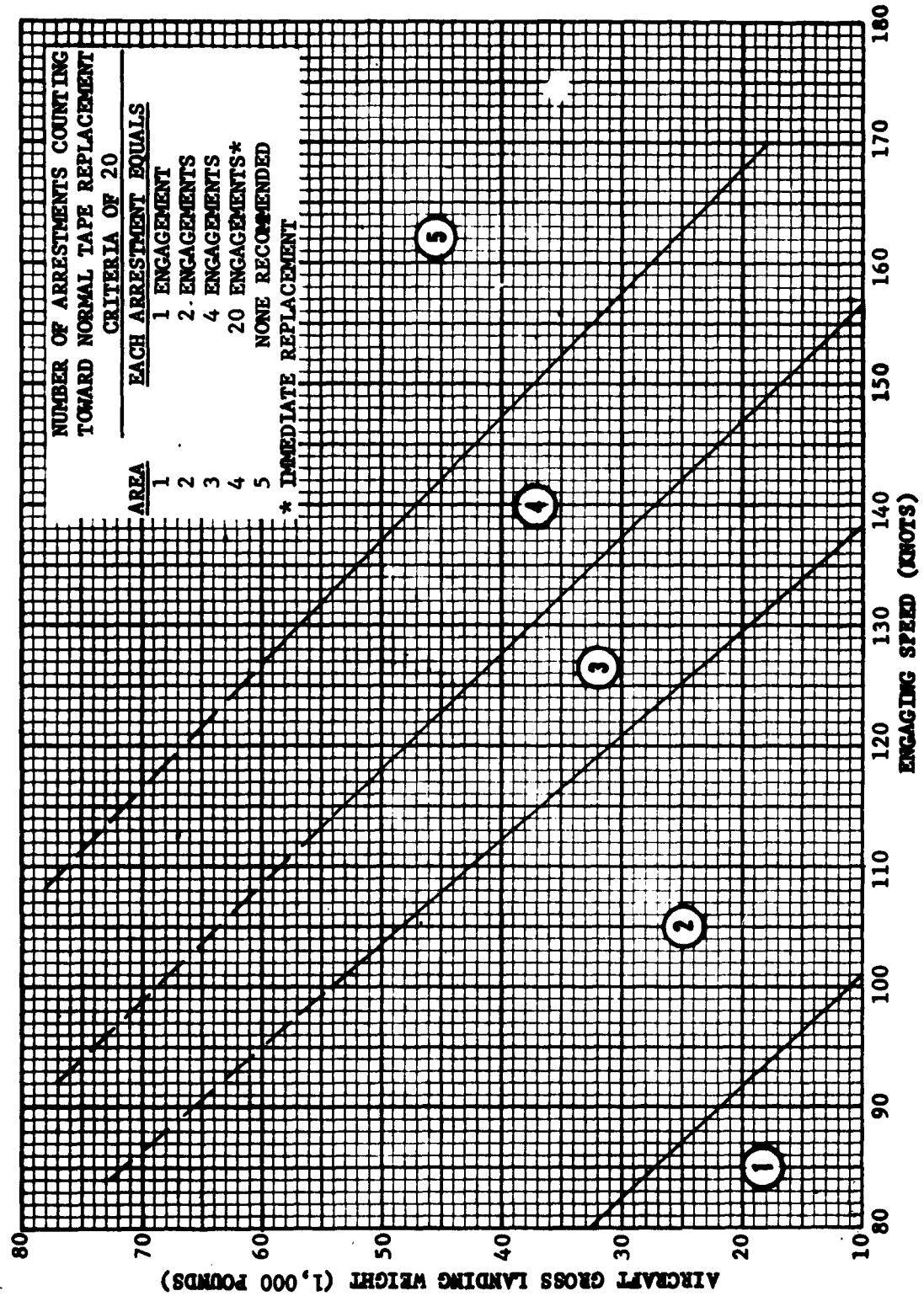


Figure 10 - Purchase-Tape Replacement Criteria for the E-27 Single-Engine Pit Installation (AAE Model 44B-2 Arresting-Gear Evaluation)

APPENDIX A - DEADLOAD TEST DATA; AAE MODEL 44B-2 ARRESTING GEAR

Date	Event		Deadload		OFF-CENTER Distance (Ft)		Engaging Speed (Kn)	Maximum				Remarks
								Purchase-Tape Tension (Lb)		Arresting-Hook Load (Lb)	Long. Decel (G)	
	Site	Proj	Weight (Lb)	Runout (Ft)	Init.	Final		Port	Stbd			
1964 30 Nov	1385	1	20,506	840	0	0	116	15,200	14,600	29,500	NV	115-ft x 1-inch-diameter pendant
"	1386	2	"	860	0	10 P	142	19,000	21,400	NV	1.45	Arresting-hook load not recorded
1 Dec	1387	3	"	868	0	3 P	155	24,000	26,100	NV	NV	Arresting-hook load and Deceleration not recorded
"	1388	4	"	885	0	7 P	185	31,300	35,500	66,800	3.18	
"	1389	5	40,622	975	0	6 S	123	16,800	18,700	34,300	1.00	Both units two-blocked
"	1390	6	"	-	0	-	145		B O L T E R			New Pendant prior to event - DL guides cut pend.
1965 6 Jan	1438	7	19,824	860	0	9 S	138	17,300	19,100	42,200	1.90	150-ft pendant
"	1439	8	"	880	0	6 S	162	27,100	30,900	48,900	2.62	
"	1440	9	"	890	0	14 S	171	28,700	29,000	63,000	3.39	
7 Jan	1441	10	29,931	955	0	0	141	22,000	21,000	42,000	1.41	New 150-ft pendant
"	1442	11	"	973	0	3 S	160	30,000	26,000	62,000	1.84	
"	1443	12	"	978	0	3 P	169	29,500	31,300	63,800	2.22	
"	1444	13	40,102	995	0	3 P	143	20,400	21,100	41,900	1.15	Both units two-blocked
8 Jan	1445	14	"	1,005	0	3 S	158	27,600	28,100	60,000	1.40	Both units two-blocked; wet purchase tapes
"	1446	15	"	1,005	0	4 S	169	33,000	28,700	75,000	1.975	Both units two-blocked; new 150-ft pendant
"	1447	16	23,922	950	0	3 S	172	31,200	34,200	60,800	2.53	

APPENDIX B - AIRCRAFT TEST DATA; AAE MODEL 44B-2 ARRESTING GEAR

1965 Date	Event		Aircraft		Engaging Speed (Kn)			Maximum				Remarks	
								Purchase-Tape		Arresting- Hook Axial Load (Lb)	Long- Decel (G)		
	Site	Proj	Type	Weight (Lb)	Runout (Ft)	SPN-12	Film	FAS	Port				Stbd
3 Feb	05	01	A-4B	15,300	700	113	121	121	12,400	12,200	16,900	1.14	
"	06	02	"	14,800	705	125	125	155	16,900	16,900	25,400	1.62	
4 Feb	07	03	"	14,300	770	131	131	150	20,600	18,500	33,800	2.10	
"	08	04	"	14,800	775	138	134	162	21,000	20,800	31,600	1.99	
5 Feb	09	05	F104	17,100	770	114	113	112	14,000	14,000	20,900	1.07	vibration in nosewheel
"	10	06	"	17,100	728	123	126	125	15,700	16,000	22,700	1.7	at pick-up
6 Feb	11	07	"	17,100	NV	142	138	142	18,500	19,500	36,400	1.95	
"	12	08	"	16,800	738	136	139	145	16,700	19,900	3,500	1.69	Slight buckling of para- chute door
"	13	09	"	17,100	NV	NV	156	164	23,800	28,800	41,000	1.80	Damage to parachute door increasing
"	14	10	"	NV	NV	137	NV	137	19,500	21,600	NV	NV	Acft had partial loss of elec - nosewheel shimmied
9 Feb	17	11	"	17,100	850	NV	173	164	30,400	28,800	58,000	3.02	

UNCLASSIFIED
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DOCUMENT CONTROL DATA - R&D <small>(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)</small>		
1. ORIGINATING ACTIVITY (Corporate author) U. S. Naval Air Test Facility (Ship Installations) U. S. Naval Air Station Lakehurst, New Jersey		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP
3. REPORT TITLE EVALUATION OF ALL AMERICAN ENGINEERING COMPANY'S MODEL 44B-2 ARRESTING GEAR WITH DEADLOADS AND AIRCRAFT		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final report		
5. AUTHOR(S) (Last name, first name, initial) Cocco, N.		
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11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Bureau of Naval Weapons (Dept of the Navy)
13. ABSTRACT A program was conducted for the evaluation of AAE Model 44B-2 arresting-gear performance. The arresting-gear performance during arrestments of 20,000- to 40,000-pound deadloads proved to be highly satisfactory, and testing was continued with A-4 and F-104G aircraft. The arresting-gear performance results from this limited program indicate it to be a desirable replacement for emergency arresting-gear systems now being used. The Model 44B-2 is compared to the three most widely-used emergency arresting gears now in use at military installations. Areas compared are energy-absorption capabilities, maximum allowable aircraft engaging speeds, maintainability, reliability, and installation.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
RECOVERY EQUIPMENT ARRESTING GEAR (EMERGENCY) PERFORMANCE EVALUATION DEADLOADS AIRCRAFT						

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